Final Report for NASA Grant NNX16AH57G
NASA FLOOD RESPONSE WORKSHOP

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1 Executive Summary

1.1 Motivation and Goal

Flooding is one of the most frequent and costliest natural disasters in terms of lives lost and destruction of property[1]. By 2050 costs of floods in coastal cities alone are said to reach $1 trillion annually[2]. Recently, globally, floods have been of exceptionally high magnitude with rainfalls exceeding record amounts as well as causing unprecedented damage in many countries (e.g. US East Coast, Malawi, Philippines, India, US Southwest, Northern England, US Mississippi/Midwest, etc.). Recent events have covered spatial scales well beyond what we have seen in the past and are frequently surpassing traditional regional disaster response coverage. In essence, these large-scale events have demonstrated that there is a need to achieve global response to flood disasters in rapid response, so that relief teams and decision-makers can have the information they need to act quickly and agencies as well as international organizations can deal swiftly with successive big events and deliver relevant geospatial data and flood imagery when and where needed all around the world.

In the case of flood monitoring and response, NASA already provides some capacity to respond through a number of research products as well as image and computer simulation products during an event, either through ongoing activities at NASA centers or through NASA project funding, all of which need be maintained and sustained. There are, of course, international relevant activities and organizations, of which NASA is part, that provide relevant services and geospatial data (USGS, NOAA, USCG, USACE, World Bank, UN WFP, CEOS, and International Disaster Charter, etc.). With this proliferation of information, it is difficult to coordinate all of those systems during one single event, let alone multiple simultaneous events or successive large events. Also, each of those systems provides a "unique" capability, and so, national and global coordination is necessary and there is probably no need to develop (yet) another system before such improved coordination takes place.

Hence, the NASA Applied Sciences Program, Disasters Program element, recognizing that NASA can play a larger role in flood response without violating their research mission or interfering the mission of recognized response entities, held a "Flood Response" workshop 14-16 June 2016. This workshop brought together various PIs and lead people from NASA's flood expert "pool" as well as many emergency managers from various national and international organizations, to discuss and formalize a coordinated domestic and global response to flood disasters and emergencies. Workshop participants included representatives from government agencies, academia, NGOs, and the private sector with a common interest in US-wide and global flood response (Figure 1.1).

Workshop Goal: The workshop goal was to enable a unique dialogue between EO mission technology & science, capacity-building and the flood response community in order to foster better coordination in flood response worldwide. More specifically, the workshop agenda set out to address these 3 objectives:

- The identification of existing NASA system, research and product owners, capabilities, and limitations. Suggest solutions/way forward for a global response to act/deliver locally with integrated solutions for decision-making
- Develop an Action Plan for a "Coordinated Response Strategy"

[1] Munich Re
[2] Hallegate et al. (2013) Future flood losses in major coastal cities. Nature Climate Change

Also desired was the goal to develop a number of complementary follow-on activities to:

- Develop a new "flood community of practice" with the SAR and the optical teams such that respective PIs will be required to periodically adjust their teams (to re-compete for multi-annual R&A funding).
- Attempt to build this into the hydrology strength at the NASA Centers, which will require discussions with relevant PIs, and initiative leads (e.g. CEOS Flood Pilot).
- Create and inform the NASA Applied Sciences Disasters Program's Flood Response Playbook

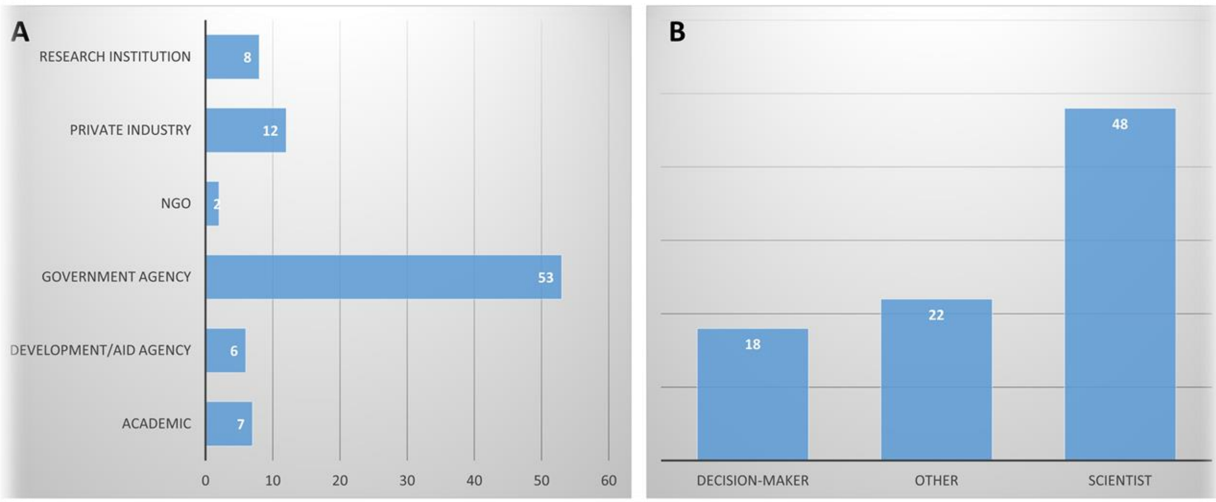

Figure 1.1. Workshop attendance by type of organization (A) and community (B).

1.2 Summary of Outcomes

Although this workshop was the beginning of a formal NASA discussion on flood response, there is a long history of disaster response efforts that were formally and informally executed in the past, such as during Hurricane Katrina and the great Tsunami in Indonesia. The workshop brought together about 70 participants from a pool of different sectors, organizations and stakeholders with a common interest in flood response (Figure 1).

Many challenges and needs were discussed and details are given in the sections that follow. These challenges and needs served as a basis to identify an action plan for the next 1 to 3 years to resolve the most imminent challenges and thus lay the path for improving the coordination of an EO-assisted flood response in the U.S. and abroad.

Although the workshop first discussed capabilities and limitations of existing response systems that utilize EO data and then laid out plans to improve flood response coordination, many of the challenges and needs identified are common to both threads and important action items identified overlap. The main issues identified and the action plan defined therefrom are listed in Table 1.1.

The EOS Meeting Report[3] also gives a short overview and a brief account of the workshop outcomes.

[3] https://eos.org/meeting-reports/flood-response-using-earth-observation-data-and-products

Table 1.1. Common and overlapping challenges/needs identified as well as the associated action that has been defined. Sections 5 and 6 will discuss these challenges and action items more in detail and also separate them out in terms of the different threads (i.e. system capabilities vs response coordination).

Challenge/Need	Action	Comment on Challenge/Need
Integrating optical & SAR (plus imagery from other agencies)	Extend SAR capabilities & integrate with optical and models (improve on each capability)	This should be a priority action
Resolve various flood detection/processing issues (cloud cover, flooded vegetation, “normal water” layer)		Can be implemented under research grants and be reported in scientific journals as well
Better flood model input/forcing data (+ reservoirs, dams & defences)		This is of high importance but may require efforts over a longer period and additional data
Routine validation of EO products & services	Routine validation & fast computation/turnaround	These are two items that should be regarded as top priority and can be resolved easily with some coordinated effort
Identify “top” EO products through vetting		
Solve restrictive data licensing	Free licensing/availability	Licensing is a top priority but may take time and HQ-level coordinated efforts from multiple agencies and other organizations
Data & products under Creative Commons licensing (open-access)		
Improve product training & feedback mechanisms	Link up services and end-users (direct involvement & feedback)	These action items are ongoing through various activities and programs such as SERVIR, CEOS, ARSET, DEVELOP etc. but need a more coordinated effort, probably with guidance from NASA HQ
Connect to private sector capabilities		
Identify point of contacts (PoC) to act ahead of disaster		
Product standardization	Create one stop shop	This is a crucial element and is easy enough to implement through inclusion in ROSES deliverables for instance
Improve product & service turnaround		Creating a one stop shop is a top priority but needs much coordinated effort and continuous management of such a site is crucial. It is recommended to build upon an existing platform, such as the Dartmouth Flood Observatory (during high impact events, the DFO already pulls and displays data from various sources
Single map display using separate layers from different products (SAR, optical, models, socio-economic data)		

2 Keynote Plenary

The goal of the *Keynote Plenary* was to give key invited guests the opportunity to present their application research and portfolio of capabilities to include experimental products, routine products developed under NASA research and applications funding.

2.1 NASA's Current Capabilities in Flood Research and Applications

D. Kirschbaum presented NASA's current capabilities in flood research and applications, including models, satellite and airborne missions including new technology, and outreach support programs. The NASA Applied Sciences Disasters Program comprises a multidisciplinary portfolio of research projects. In 2015, the NASA ROSES 2011 project portfolio contained ten projects that were in year two of the full-scale applications development phase. The projects are listed in Table 2.1.

Table 2.1. NASA ROSES 2011 project portfolio.

AWARD1	Start Date	Project	PI	Affiliation
A33 Phase 2	Oct-14	GPS-Aided and DART-Ensured Real-time(GADER) Tsunami Early Detection System	**Tony Song**	JPL
A33 Phase 2	Aug-14	Developing global building exposure for disaster forecasting, mitigation, and response	**Ron Eguchi**	ImageCat, Inc..
A33 Phase 2	Aug-14	Disaster Response and Analysis Through Event-Driven Data Delivery (ED3) Technology	**Sara Graves**	UAH
A33 Phase 2	Aug-14	Using real-time GPS/seismic displacements to improve disaster management and decisions pertaining to rapid assessment of structural risk and damage from earthquakes	**Yehuda Bock**	Scripps
A33 Phase 2	Aug-14	A Remote-sensing-based Flood Crop Loss Assessment Service System (RF-CLASS) for Supporting USDA Crop Statistics and Insurance Decision Making	**Li Ping Di**	GMU
A33 Phase 2	Sep-14	Enhancing Floodplain Management in the Lower Mekong River Basin Using NASA Vegetation and Water Cycle Satellite Observations	**John Bolten**	GSFC
A33 Phase 2	Aug-14	Near Real Time Flood Inundation Prediction and Mapping For the World Food Programme	**Robert Brakenridge**	U of Colorado
A33 Phase 2	Jun-14	Enhancement of the NWS Storm Damage Assessment Toolkit with Earth Remote Sensing Data	**Gary Jedlovec**	NASA MSFC
A33 Phase 2	Jul-14	Near Real-time Volcanic Cloud Products for Aviation Alerts	**Nickolay Krotkov**	NASA GSFC
A33 Phase 2	Sep-14	SAR-VIEWS: SAR Volcano Integrated Early Warning System	**Franz Meyer**	Univ. of AK

Since Disasters is a unique area of Applied Sciences which also utilizes its project's applications products to the greatest extent possible to actively support Disaster planning, response and recovery, a secondary portfolio of projects comprising other core capabilities is also maintained. These activities which were covered in 2015 are listed in Table 2.2.

Table 2.2. Portfolio of projects comprising other core capabilities.

AWARD	Start Date	Project	PI	Affiliation
GEOIM-10[1]	Feb-14	Deformation monitoring of volcanoes in the Caribbean and Latin America using ALOS-PALSAR and Sentinel-1 interferometry	**Falk Amelung**	U of Miami
GEOIM-10[1]	May-14	Damage Assessment Map from Interferometric Coherence	**Sang-Ho Yuen**	JPL
AIST-11[2]	Jun-13	Next-Generation Real-Time Geodetic Station Sensor Web for Natural Hazards Research and Applications	**Yehuda Bock**	UCSD
AIST-11[2]	Jun-13	Advanced Rapid Imaging & Analysis for Monitoring Hazards (ARIA-MH)	**Hook Hua**	JPL
RR2014[3]	Jul-14	Norway Oil Spill Exercise 2014-15	**Cathleen Jones**	JPL
Directed[4]	Oct-10	MODIS Flood Mapping Transition	**Fritz Policelli**	NASA GSFC
A33-F2D[4]	Feb-14	Real-time Global Flood Analyses and Forecasts Using Satellite Rainfall and Hydrological Models	**Robert Adler**	UMD
Directed[5]	Jun-25	Support for NASA's CEOS DRM Flood Pilot	**Brian Killough**	LaRC/SEO
Directed[6]	Oct-1	Development of and Integration of a High Resolution 2-D flood Model with Satellite Flood Data	**Guy Schumann**	JPL

Those projects that relate more specifically to flood disaster response science and applications are described in more detail in Appendix A.

2.2 Keynote talks

2.2.1 *S. Medlock: Office of Management and Budget, White House*

S. Medlock gave an excellent "food for thought" keynote talk on day 2 of the workshop. She highlighted that post-Katrina, levee safety was the way forward but there was a policy change after Sandy with the climate action plan. There is now a need for science, data and visualization to make development decisions. In other words, integrate science into policy and practice, and use science for recovery, too. Climate change is altering the picture and demands to include resilience and preparedness.

S. Medlock also noted the challenges related to the standard of the 1:100-year flood and associated floodplain. This has been mostly grounded in insurance, and was built on a compromise; and has also been grounded in standard practice to decide how and where to build. However, there is now a general feeling and consensus among State and local government that this may no longer be adequate. Rather one should see the entire floodplain as a floodway and definition should be based on higher standards in public safety as well as science.

This need of change is further reinforced by the fact that >40% of the losses can be outside of the 100-year floodplain. In fact, the Executive Order 13690 revisits how to site, design, build around floodplains. The significant changes include the use of the 500-year (or 0.2% probability) floodplain, where known, and utilize climate-informed science to inform development (preferred). However, this information does not exist in many places, so there are no maps for this, much less a well-defined floodplain. Agencies active in establishing flood risk standards, such as FEMA and USACE are now required to take future condition into account, and other agencies, such as NASA and NOAA have additional data and expertise to assist; NOAA is participating in teams to inform this new flood standard.

2.2.2 *L. Friedl: Applied Sciences, NASA*

As second keynote talk on day 2 was given by the director of the Applied Sciences Program at NASA, L. Friedl. He highlighted a number of issues (e.g. different data formats, many products, what does operational mean and where does NASA fit in) and gave some recommendations/suggestions on how to move forward. For instance, there is a clear need to articulate when the data are used to make decisions and this need to be clearly specified. At the moment, it is unclear what specific decisions are being helped. There is also a need to articulate research and applications needs (input to the Decadal Survey is vital here).

L. Friedl also encouraged open data, especially at EU and ESA level since, particularly in flood-related applications, NASA is increasingly dependent on other space agencies (e.g. ESA for Sentinel-1 data) and so better coordination is needed.

In disaster response, low latency (a few hours) is key and L. Friedl noted that such requirements are-recognized and needs should be defined in pre-mission Phase-A because it is difficult to add mission requirements later. D. Green noted here that although NASA this low latency is not really operational, there is the potential for real-time and near-real-time science, and he stress that this does not change the fundamentals of what NASA does. For example, science teams intervened with CYGNSS and NISAR before launch to receive data more rapidly.

V. Escobar also noted that it is necessary to add social science to the "hard" science and the question of how the way we look at disasters can be readjusted is also important.

2.3 Summaries of Invited Talks

All the invited talks are available for download at https://pmm.nasa.gov/meetings/restricted/2016-flood-response-workshop.

2.3.1 *NGA: B. Cameron*

The National Geospatial Intelligence Agency (NGA) is a military support agency that primarily uses commercial high resolution imagery. NGA provides timely relevant damage assessments and flood extents through commercial imagery for affected areas (Figure 2.1), which are prioritized by FEMA. NGA provides mission partners with shapefiles and finished PDF map graphics of affected areas. During an event their team requires daily communication with local, state, and regional response officials in order to adjust their remote sensing plan. We work closely with the NOAA liaison to FEMA, NWS, and other agencies in order to define specific affected areas.

As the main challenges in terms of flood response that NGA faces, B. Cameron listed flash flooding, identification of populated areas which are affected, as well as prioritization and timing. Furthermore, NGA would use NASA (i.e. satellite and airborne) data and developed models to provide FEMA with training and tools in order to exploit NASA sensors for flooding. With regard to assisting NGA in supporting flood response, NASA could look into (i) automation of anomalies (damage assessments), and (ii) partnering with USGS, Army Corps, and The Water Center to discuss how high water gauge recordings could be used to automate satellite collection.

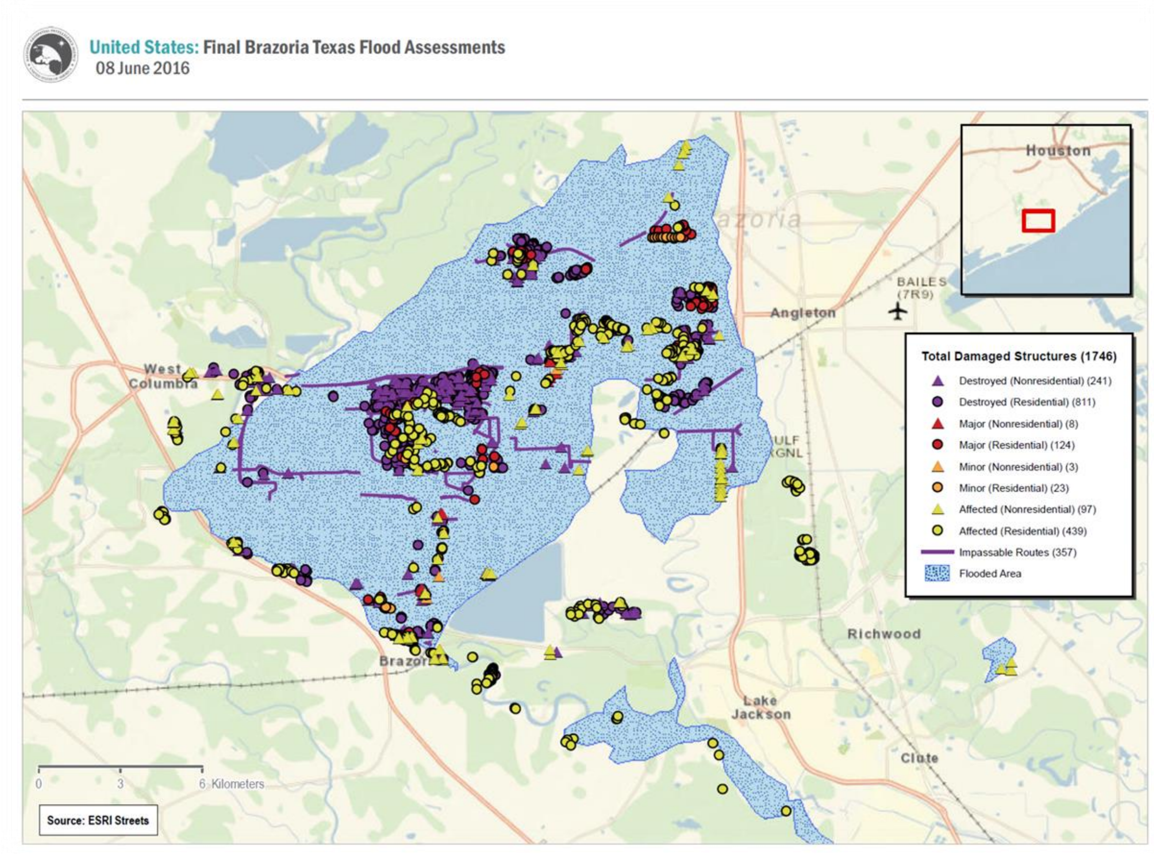

Figure 2.1. Example NGA map providing relevant damage assessment and flood extent through commercial imagery for affected areas.

2.3.2 *FEMA: C. Vaughan*

C. Vaughan outlined FEMA's "Flood Whiteboard" and began by pointing out while knowledge and response related to tornadoes and hurricanes get better and hurricanes actually receive significant coverage and research, flooding, especially from rainfall receives far less attention. As many recent examples (e.g. Texas, S. Carolina, etc.) indicate, every agency is quickly overwhelmed and there is little warning.

Also, data and product redundancy and overlap during major flooding is of great concern. (e.g. ~40,000 maps were produced made for Katrina). Although, there may be notable capability (e.g. USAF and EagleVision SAR, or airborne camera from the Civil Air Patrol), there is a need to get a handle on these types of flood events and ensure assessments (damage) are done as best as possible (e.g. S. Carolina number of homes damaged: 10k initial estimate vs 40k actual). Here, C. Vaughan pointed out that precision and accuracy from remote sensing may not be important at the start, numbers can be confirmed and adjusted later by field operations; having an initial good estimate of "where" and "how much" is vital (e.g. within ±5000 damaged homes). Also knowing the location and effect of small earth dams is crucial. Failure of these dams causes significant flooding but they are not included in models. C. Vaughan also pointed out the need to have units converted from SI (International System of units, such as used by UMD's GFMS) for easy integration in domestic (US) response operations.

FEMA has HAZUS[4] to produce flood risk maps (Figure 2.2) for the Flood Insurance Program but "It's everywhere it's not supposed to be" and there is a need for FEMA to have a map of structures. FEMA would like to see "unified flood products" that can be linked to structures. NOAA is helping with forecasts but they only look at gauges whereas FEMA actually needs a map of the flood boundary to vulnerable populations. Currently, it can take FEMA up to 6 months to do this assessment, instead they would like a timely map that gets them close to the size of the disaster and ground teams can "tighten up the numbers" later. Here locations of rain-induced flooding is crucial. Riverine flooding is easier to estimate, simulate and observe but events of impact are oftentimes off the big floodplains in locations not instrumented, simulated or observed.

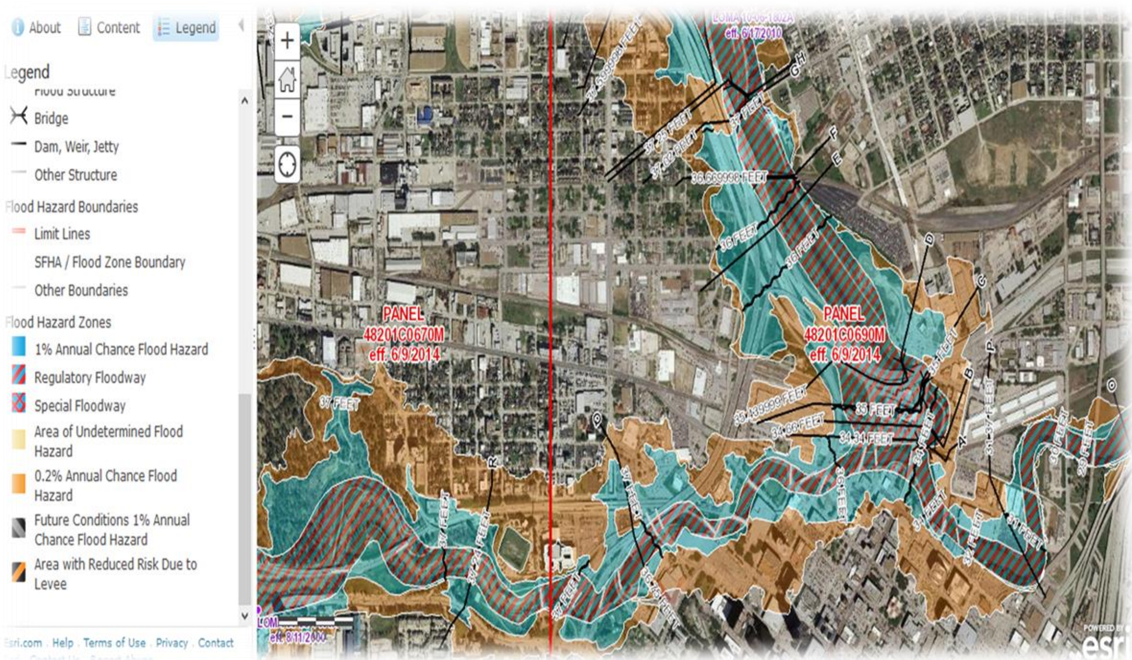

Figure 2.2. Typical FEMA flood risk map.

2.3.3 *VDEM: M. Slauter*

The Virginia Department of Emergency Management (VDEM) is responsible for coordinating the state's emergency preparedness, mitigation, response and recovery efforts. It uses a proprietary commercial platform, but this has too many overlapping data sets and symbols, which is overwhelming and confusing, so VDEM created a flood disaster-tailored version for VA (Virginia Flood and Observation Network, Figure 2.3), which pulls data from NOAA and USGS (Water Watch).

Since very few people know what the stream gauge data mean and how the measurement actually relate to a given river and its relation to an inundated surface on the floodplain, VDEM's main challenges are: (i) figuring out the spatial extent of real-time as well as forecast inundation; (ii) getting timely visual representations of inundation; and (iii) have access to inundation modeling capabilities.

[4] Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes**.** Hazus uses GIS technology, building models, and population data to estimate physical, economic, and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane and floods.

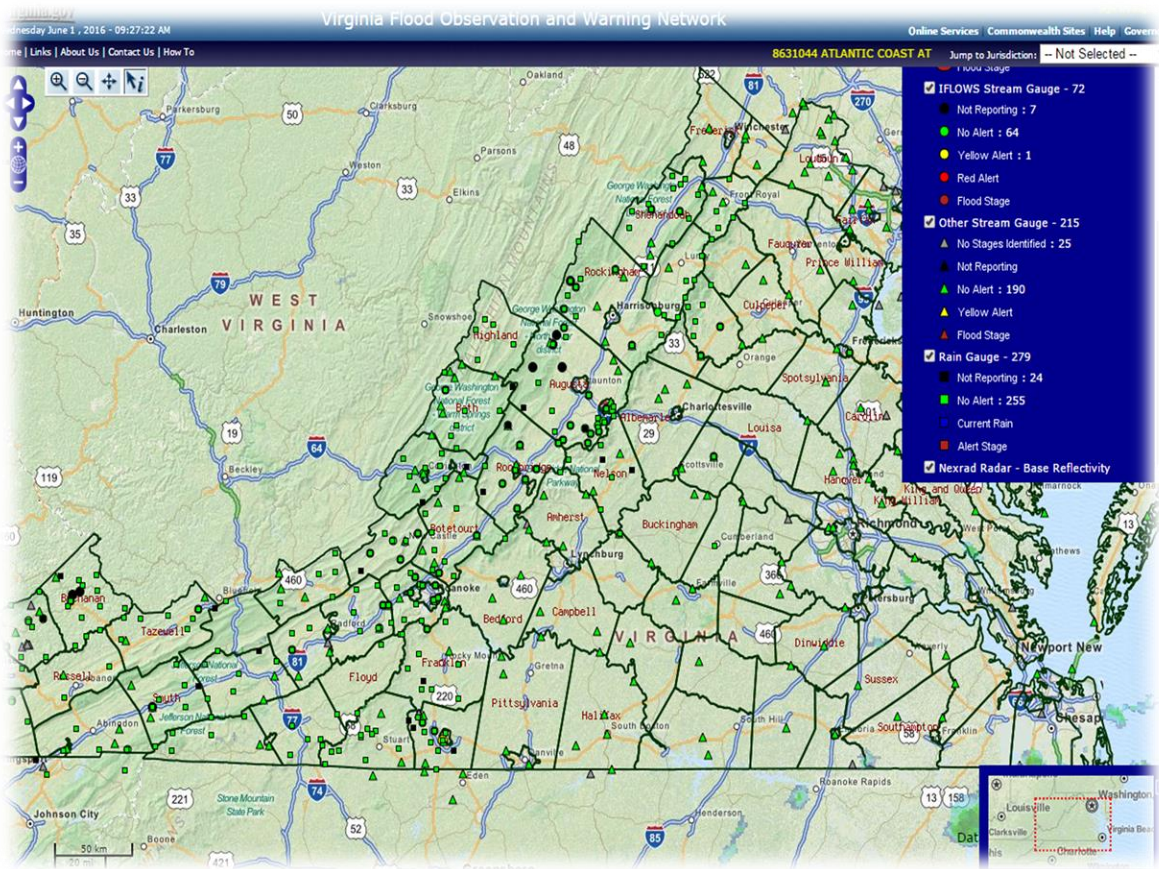

Figure 2.3. The VDEM “tailored” flood disaster portal.

2.3.4 *NOAA NWS: S. Smith/K. Abshire*

S. Smith presented an overview of the NOAA National Weather Service (NWS) Office of Science and Technology Integration (STI). The STI’s goal is to improve effectiveness of field R2O (Research to Operation) through central coordination and resource management. It transitions and enhances operational models through integrative research advancements, improved model guidance, and gets decision support system (DSS) tools into field operations. STI’s scope (Figure 2.4) also includes social science integration, training development, as well as support of targeted collaborative applied R&D. S. Smith noted that ST uses readiness levels (RL) but they rarely move beyond demonstration at RL 8.

K. Abshire, representing the National Water Center (NWC) in Tuscaloosa, Alabama, gave an overview of the development of the National Water Model (Figure 2.5). Currently, the NWS provides inundation at gauges: only 137 across the country. K. Abshire acknowledges that this is not sufficient. The NWC services decision support stakeholders and tries to focus on flooding-blind areas. The National Water Model will provide spatially continuous streamflow modeling and potentially forecasting of the entire network at fine scales. Dissemination would be via the web, to field offices, and also through the National Operational Model Archive and Distribution System (NOMADS).

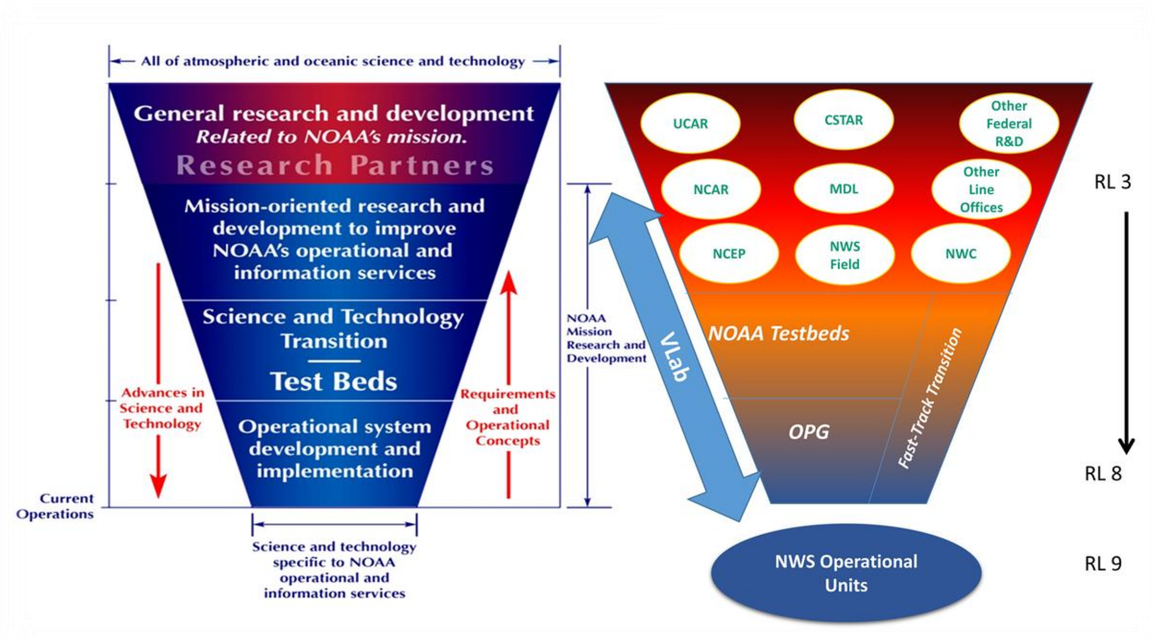

Figure 2.4. Overview of STI's R2O structure (© S. Smith, Director, NOAA VLab).

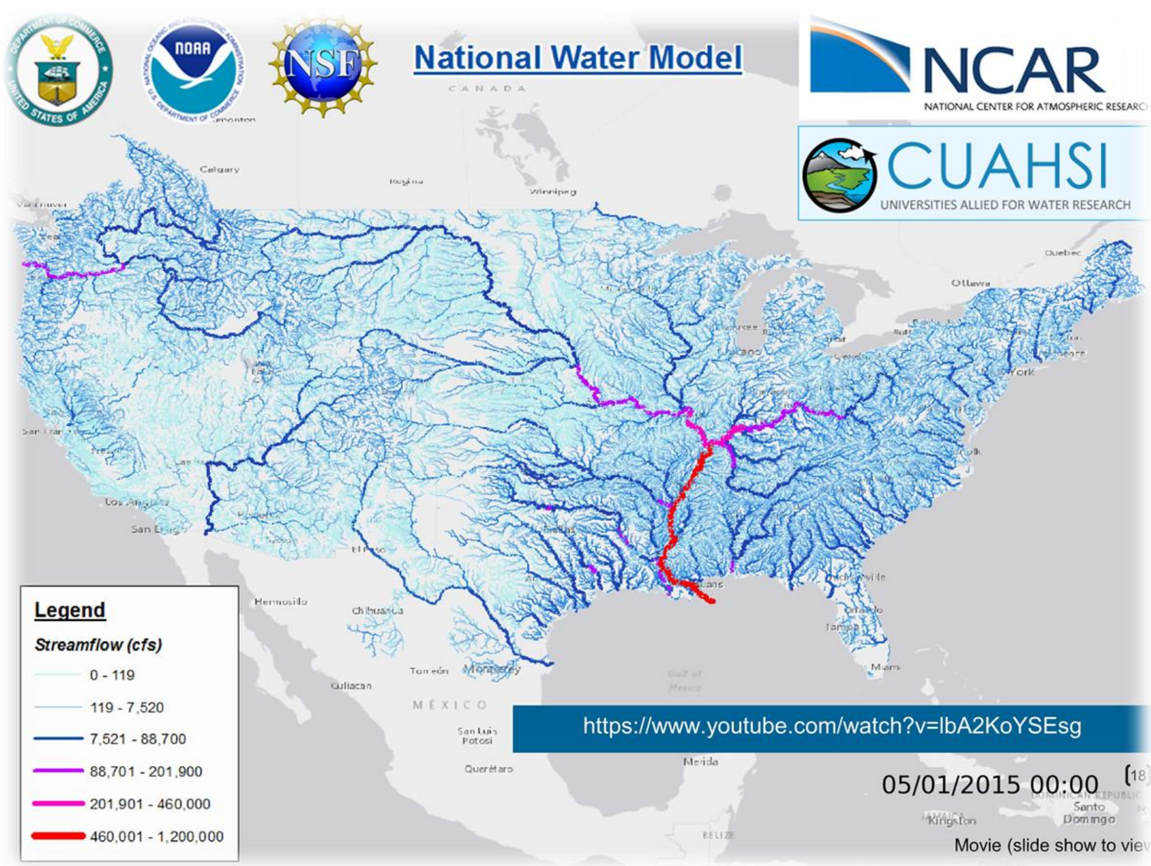

Figure 2.5. Illustration of the on-going development of the National Water Model.

2.3.5 *USGS: H. Jenter*

H. Jenter from the USGS Office of Surface Water presented USGS's capabilities during flood events and an overview of flood-related data (http://waterdata.usgs.gov/nwis, Figure 2.6), available mostly over automated web services so agencies can pull data to their own DSS. Generally speaking, the USGS provides and assists with the following:

- Coordinate with local, state and Federal agencies (e.g. USACE, NOAA and FEMA)
- Collect and disseminate water data (stage, flow, high water marks, sediment and water quality) using permanent and temporary networks of sensors as well as other non-networked instrumentation Other instruments include acoustic Doppler velocity measurements; 4 Hz pressure sensors for flood waves, storm surge and tide. Meteorological stations with radar measurements of water height; these are deployable for velocity and discharge.
- Event-specific flood inundation mapping
- Collect and disseminate airborne and satellite imagery (hddsexplorer.usgs.gov)
- Forecast and map probability of coastal change
- Create and disseminate analysis products and reports
- Flood event viewer (https://stn.wim.usgs.gov/FEV): online GIS-based data viewer for storm response (events remain active once set up).

With pre-scripted mission assignments and/or timely outside funding, the USGS can provide quite comprehensive, customized and timely information to its partners. Also, the USGS's response is flexible with the circumstances. New capabilities are allowing the USGS to respond with higher quality, targeted and easily accessible information.

Table 2.3. Key USGS Coordinators for Floods

Name	Email	Role
Greg Shelton	gshelton@usgs.gov	USGS Emergency Management Coordinator
Bob Holmes	bholmes@usgs.gov	USGS National Flood Hazard Coordinator
Jim Stefanov	jestefan@usgs.gov	USGS Storm Team Leader
Brenda Jones	bkjones@usgs.gov	Disaster Response Coordinator, USGS EROS Center
Marie Peppler	mpeppler@usgs.gov	USGS Flood Inundation Mapping Coordinator

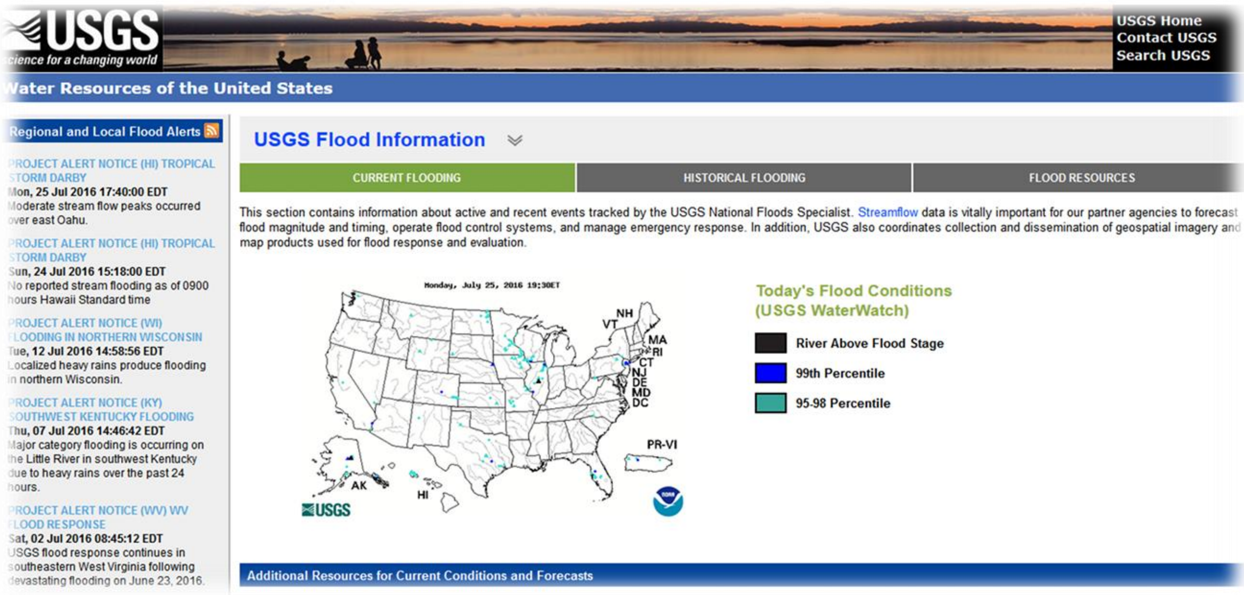

Figure 2.6. USGS Water Watch (http://waterwatch.usgs.gov/?id=ww_flood). See also: http://water.usgs.gov/wateralert

2.3.6 *USAID/OFDA: S. Tokar/B. Bartow*

USAID, through the Office of Foreign Disaster Assistance (OFDA), leads the U.S. Government response to natural and man-made disasters internationally. USAID's policy is that in order for aid to be offered (i) the disaster must be beyond ability to respond; (ii) the requesting entity must be willing to accept U.S. aid; and (iii) the disaster response must be in the U.S. interest.

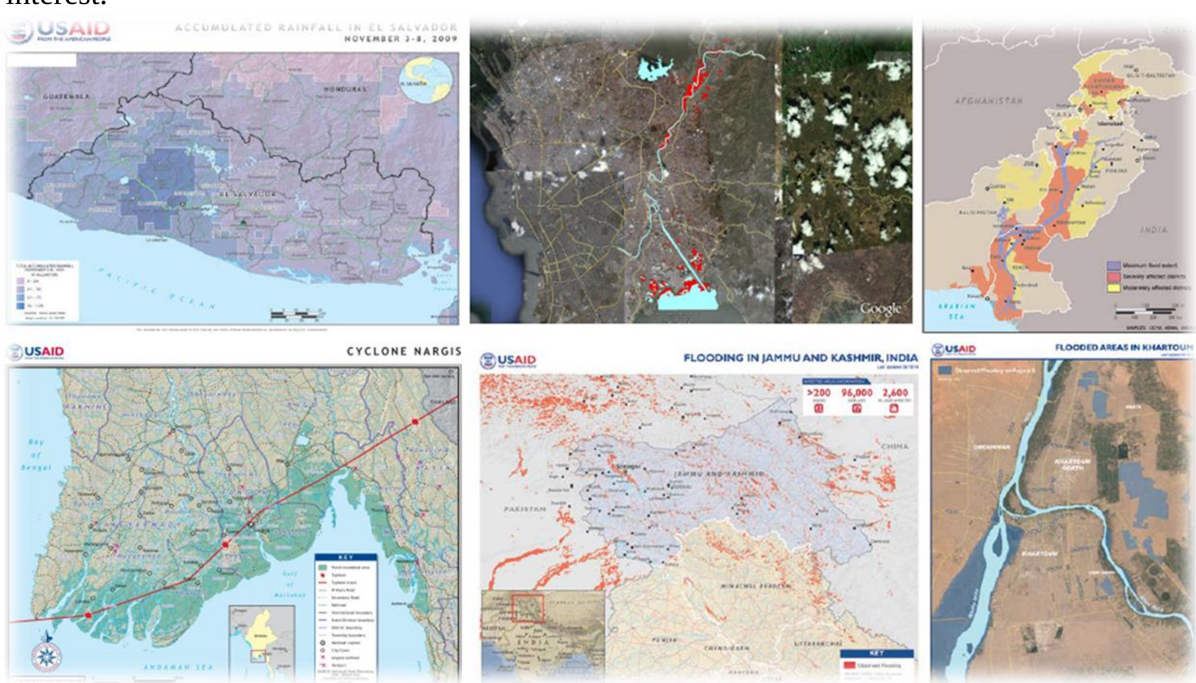

Figure 2.7. Examples of flood data used by OFDA.

There are around 400 disasters a year, globally and the U.S. Government responds to about 50-60. Complex emergencies (involving more than one disaster type) are top priority, followed by floods, which typically need substantial budget in aid. A considerable challenge OFDA highlighted is to “go where to find what”.

2.3.7 *USACE: C. Pathak/J. Eylander*

C. Pathak from the US Army Corps of Engineers (USACE) presented the Corps Water Management System (CWMS) for real-time public support, which includes all USACE in-house software tools and decision support systems and is applied for hydrologic forecasting (HEC-HMS), water management simulations for reservoir release scheduling (HEC-ResSIM), hydraulic simulations for inundation (HEC-RAS), and consequences estimates performed with HEC-FIA for damage and cost-benefit analysis. CWMS is using hydrologic/hydraulic spatially distributed simulation models (developed outside CWMS and then linked together) for short-term forecasts and event scenarios such as future precipitation amounts and timing, reservoir operations, and levee failures (14,500 miles of levees).

The CWMS National Implementation Plan looks at USACE’s nationwide water management role (201 watersheds throughout the US) and is being implemented by teams coordinated by the Mapping Modeling and Consequences Center (MMC). Sixty watersheds have been operational by the end of 2015 (Figure 2.8) and completed models are used by local district offices for daily water management activities and additionally used for other activities such as emergency management, planning studies, dam and levee safety.

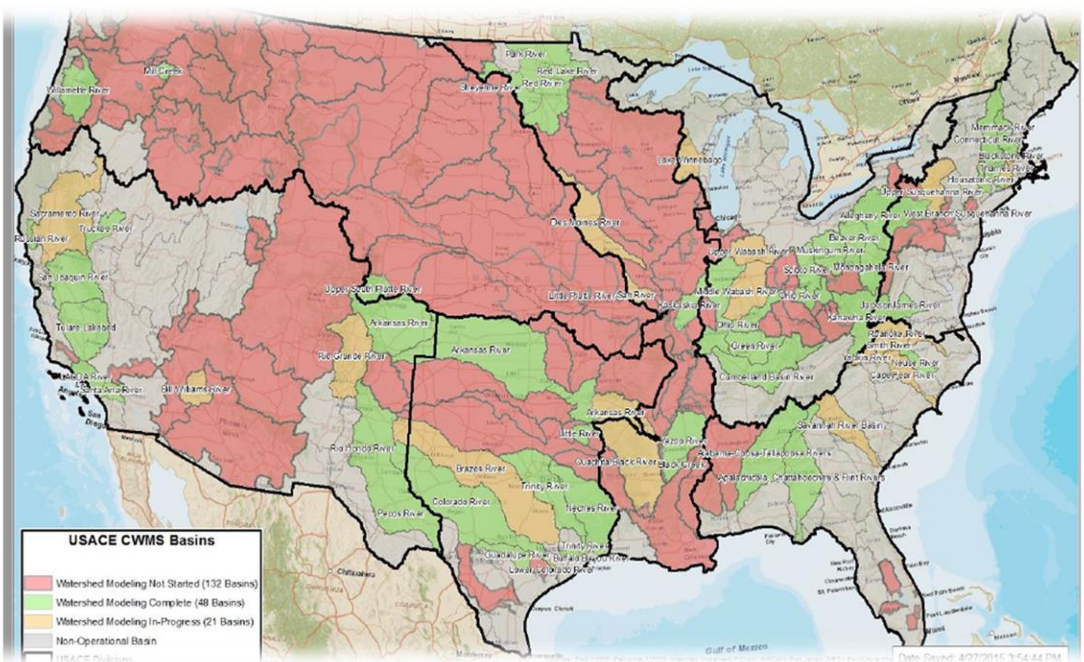

Figure 2.8. Watershed map illustrating the progress of the CWMS National Implementation Plan.

J. Eylander from the US Army Engineer Research and Development Center (ERDC) outlined ERDC’s capabilities to support operational hydrologic analysis and prediction. They use a variety of weather-terrain-hydrology linked models to provide global support to military operations, so that international foreign assistance can be supported. For instance, predicting floods and their human consequences can alert the Army to deploy support for disaster relief and prepare for mass migration. ERDC investigates new methods of linking environmental models with geospatial products and develops tailored products. This allows delivery of appropriate information suited for decision making through the Army enterprise geospatial information systems. Products are often map-based and ERDC develops interactive direct data-to-decision applications. This information is needed for both its impacts on the economy and military operations.

Figure 2.9 illustrates the structure of the military hydrology and decision support. J. Eylander also noted that no organization is responsible for hydrology in the military and although there is a policy, there is no official instruction to engage and be very active in this field. A possible solution would be to bridge capabilities with the available resources

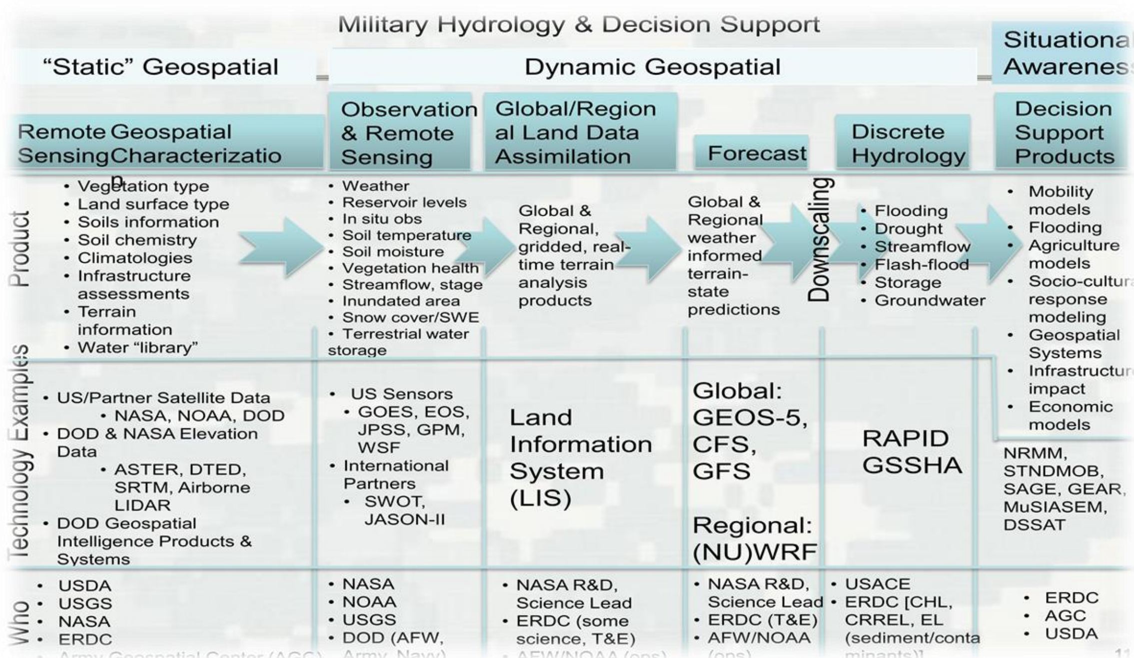

Figure 2.9. Structure of the military hydrology and decision support.

2.3.8 *UT Austin and Texas Emergency Management: G. Wells/T. Howard*

UT Austin's Center for Space Research (CSR) runs the Texas state operations center. G. Wells pointed out that it is important to know the impact on properties, insured/uninsured, and there is a need to show >$34.5 M in damage (across the state, that is $1.41 per person). The operations center currently uses a lot of Civil Air Patrol photographs and also satellite imagery from NASA when and where available for situational awareness (Figure 2.10). G. Wells would like to see the process rationalized, made more effective and efficient, and would like to see how spaceborne observations could be useful to State level response.

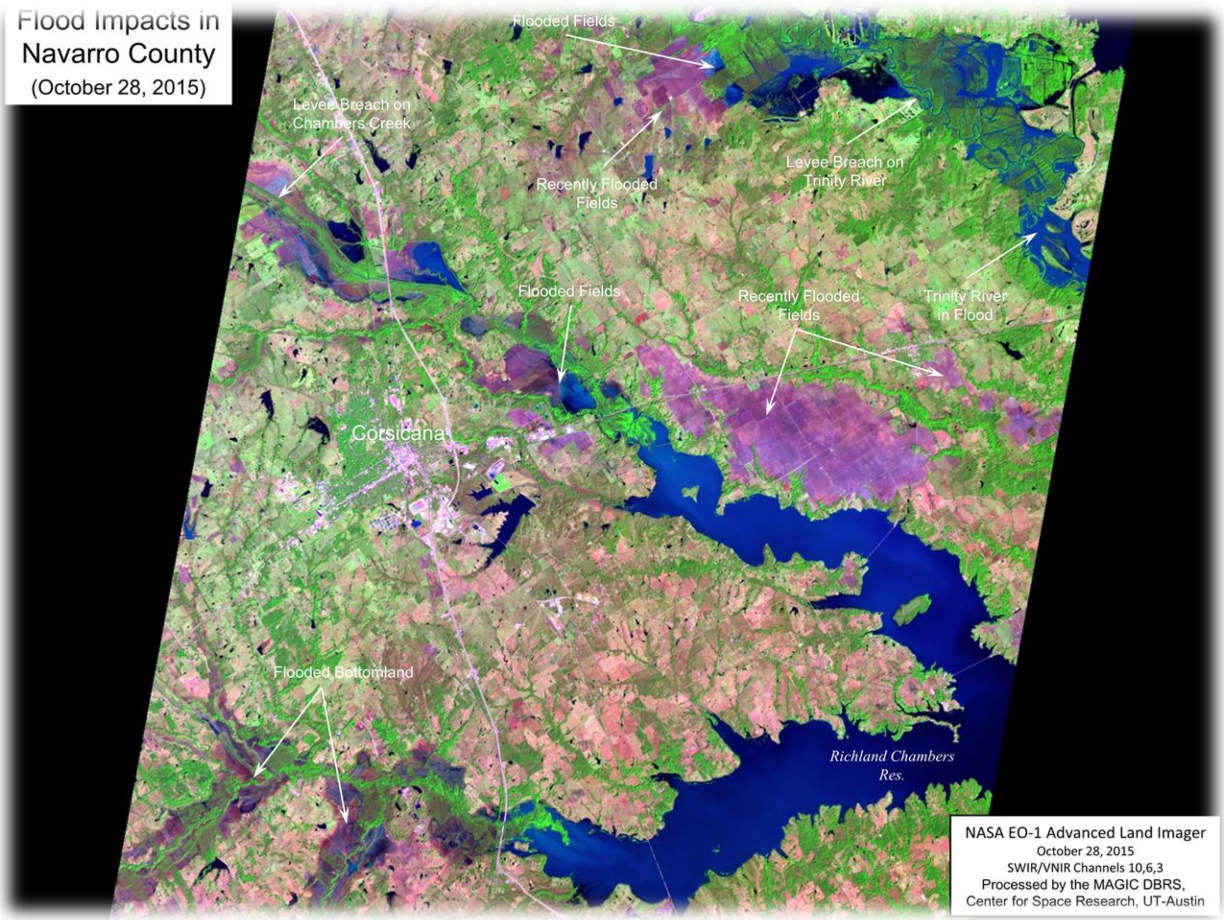

Figure 2.10. Sample satellite image used for "situational awareness" assessment during a flood disaster.

2.3.9 *IAEM: D. Spiewak/B. Goldhammer*

The International Association of Emergency Managers (IAEM) is a professional association of volunteer members. IAEM supports education, outreach, and training. Their goal is networking, preparedness and data sharing. The use, purpose and value of data for local managers are important. Agencies such as NASA, USGS, USACE, and NOAA need to collect the data and put it into one spot, and make it usable. D. Spiewak pointed out the need for model uncertainties and errors, probabilities, and maps. Furthermore, he identified three major challenges: data have to be understandable (e.g. divide the probabilities into three simple levels, e.g. most likely, likely, least likely), in a basic format, and current. Situational awareness is crucial too. It is also important to geocode photographs and pictures: and relate pictures of water levels to public buildings.

B. Goldhammer also pointed out the importance of moving away from the notion of the 100-year flood.

2.3.10 *IRI for Climate and Society/ International Red Cross: A. Kruczkiewicz*

A. Kruczkiewicz reported on his experience in Africa during major flood disasters. It is clear that there is still a connect forecasters (and product developers) to those who know how to take action, even in countries with very small staff. In Malawi, for example, several flood map products were delivered to the ground teams but they did not know how to use them (they want to know "which one is the best"; note: Pietro Ceccato had a DEVELOP project to determine which of these maps was best). Riverine flood maps may work well but A. Kruczkiewicz noted the concern with flash floods, particularly in countries like in Africa with rapid, informal urbanization into mountain valleys with flash flood problems where some communities can be completely wiped out in a storm. Knowledge on flood type is also crucial and Kruczkiewicz also highlighted the importance of preparedness, vulnerability and risk assessment, and recommended co-production of outputs and products with the help of end-users.

In conclusion, A. Kruczkiewicz suggested a shift (within the Red Cross) to *forecast-based financing* (Figure 2.11) where the idea is to send help ahead to spend early, lessen the need, and then spend some more later, with the expectation that the total cost would turn out smaller than with a non-forecast-based response.

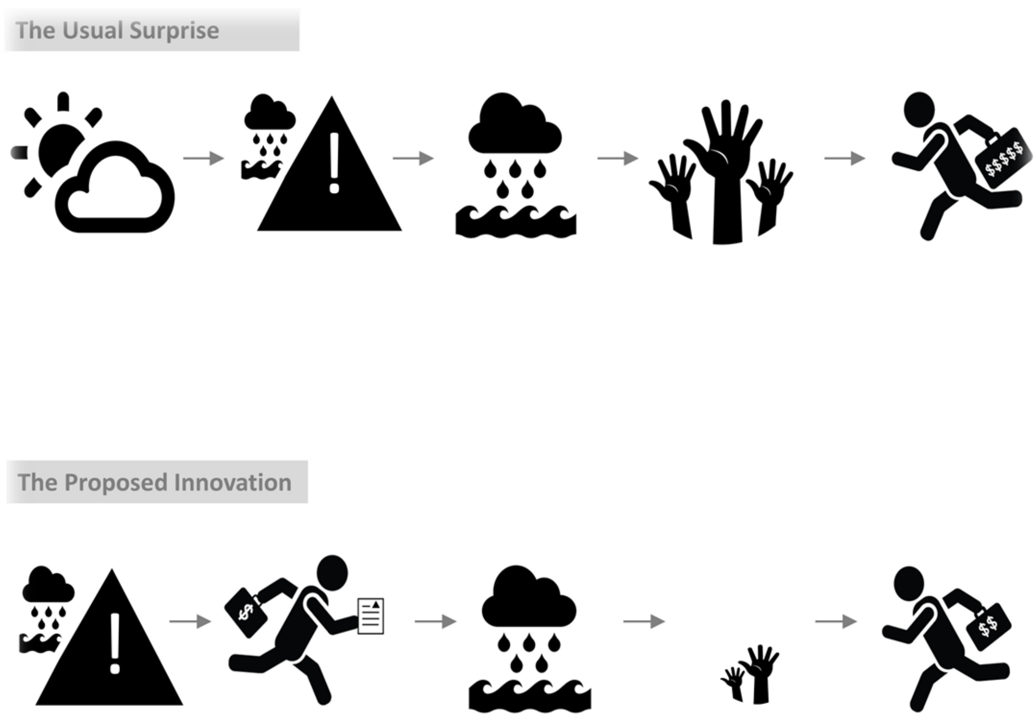

Figure 2.11. Planning for *forecast-based financing*.

2.3.11 *UN World Food Programme: K. Rashid*

K. Rashid presented experiences from the UN WFP. He pleaded for a "loud and clear" message during (flood) disasters, so there is no need to filter out the "noise". He also highlighted issues of lack of knowledge and awareness of how to use data and products provided of the people affected, as well as responders, but also the scientists. For instance, he noted an example where the UN WFP received free access to forecast data from ECMWF but nobody knows how to deal with this information and file (transfer) size. Nonetheless, K. Rashid welcomes and praised the value of the NASA NRT global flood maps from MODIS but stresses the issue of cloud cover during many events and that a "SAR equivalent" is much needed.

He also highlighted the need to (better) communicate with local flood experts—those who have been forecasting and dealing with floods for years. Combining that local flood knowledge with modern forecasting tools could be very powerful – see Figure 2.12 as an example of mismatch between modeling of flood-prone areas and actual affected areas during a high magnitude event. K. Rashid also argues that accountability of large relief organizations is needed somewhere along the line and that lessons learned should accumulate. Furthermore, he pointed out that in large organizations senior management changes frequently and the way forward is to pick a good focal point, find a personal contact and then work out what happens when that person leaves.

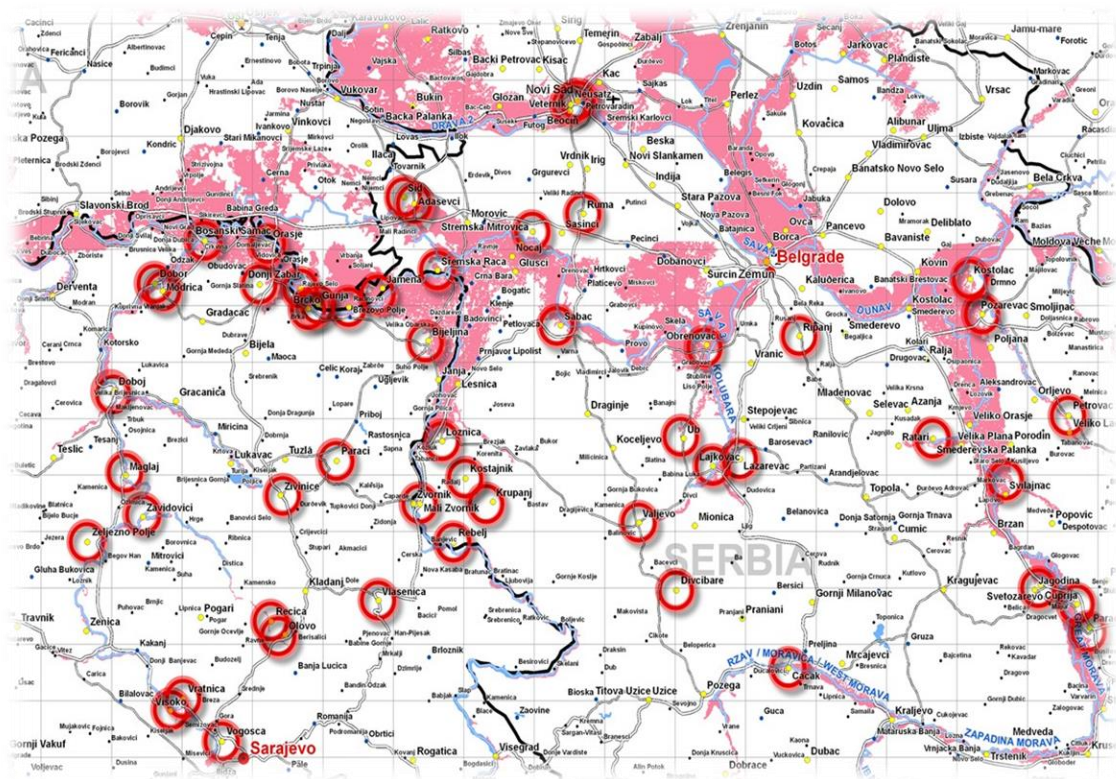

Figure 2.12, Example of mismatch between modeling of flood-prone areas and actual affected areas during a high magnitude event in the Balkan countries.

2.3.12 *International Charter, USGS/CEOS: Brenda Jones/Stu Frye*

Brenda Jones from USGS presented the services offered by the USGS HDDS (Hazards Data Distribution System, http://hddsexplorer.usgs.gov), the EIS (Emergency Operations Ingest System), the CMT (Collection Management Tool, http://cmt.usgs.gov) as well as by the International Charter (https://www.disasterscharter.org).

The HDDS (Figure 2.13) provides a consolidated storage and point-of-entry system for access to all USGS-hosted datasets related to emergency response, with two types of access:

- Public: unrestricted access for general public;
- Restricted: password-protected access for designated emergency response personnel; generally, contains licensed data not intended for public use. All requests for Restricted access are submitted and approved on event-by-event basis.

The EIS ingest provides:

- Standardized product packaging and format;
- Map-based, interactive searching and browse/footprint viewing capability on graphical HDDS2 requires ingested data;
- Metadata query and filtering capability;
- Georeferenced metadata and browse files to support user search and communications functionality (e.g. shapefiles, KML).

The CMT allows users to submit and monitor Data Acquisition Requests (DARs) and view public image requests and areas-of-interest (AOIs) that have been submitted by other users. The tool includes direct linkage to HDDS, allowing users to view available imagery for active EO events. It also provides automated email notification as imagery is collected in support of a request.

All the above services and tools as well as information about the International Charter are outlined on the Emergency Operations Web Portal (http://eoportal.usgs.gov).

Figure 2.13. The USGS HDDS.

Stu Frye represented CEOS (Committee on Earth Observation Satellites, http://ceos.org) within GEOSS (Global Earth Observation System of Systems) and its global flood pilot (http://ceos.org/ourwork/workinggroups/disasters/floods) led by the Disasters Working Group.

The flood pilot of CEOS aims at getting some free data from multiple space agencies as well as from the International Charter since this increase capability to image multiple areas at once. Commonly, CEOS provides underlying data as well as imagery during events.

Stu Frye noted that on web interfaces, such as their Namibia flood dashboard (Figure 2.14), it would be helpful to turn map and data layers on and off and to be able to retrieve, download individual layers from the site as needed.

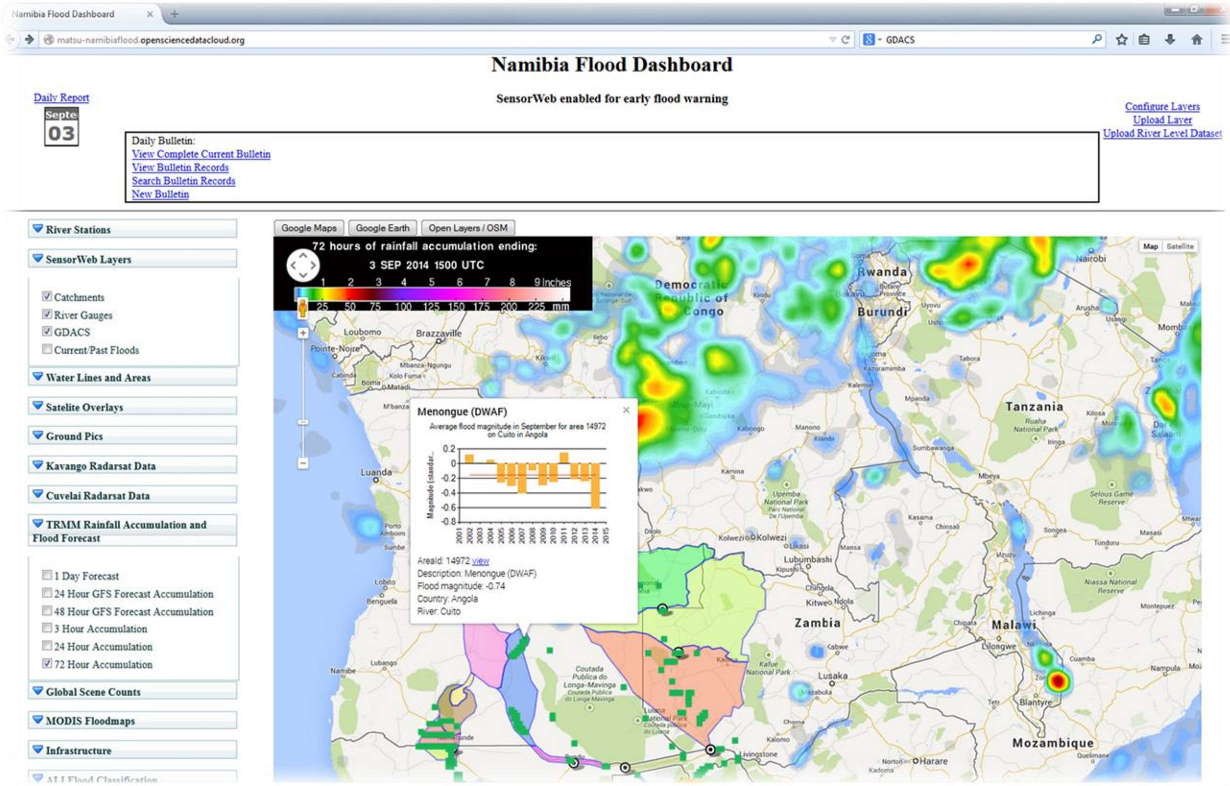

Figure 2.14. The Namibia “Flood Dashboard” (example of a one stop shop).

3 Flood Response Poster Exercise

During the workshop attendants were asked to write their (product) capabilities and needs on posters (Figure 3.1.) using sticky notes to mark where those would fit best in terms of disaster "task/role", i.e. mitigation, preparation, response or recovery.

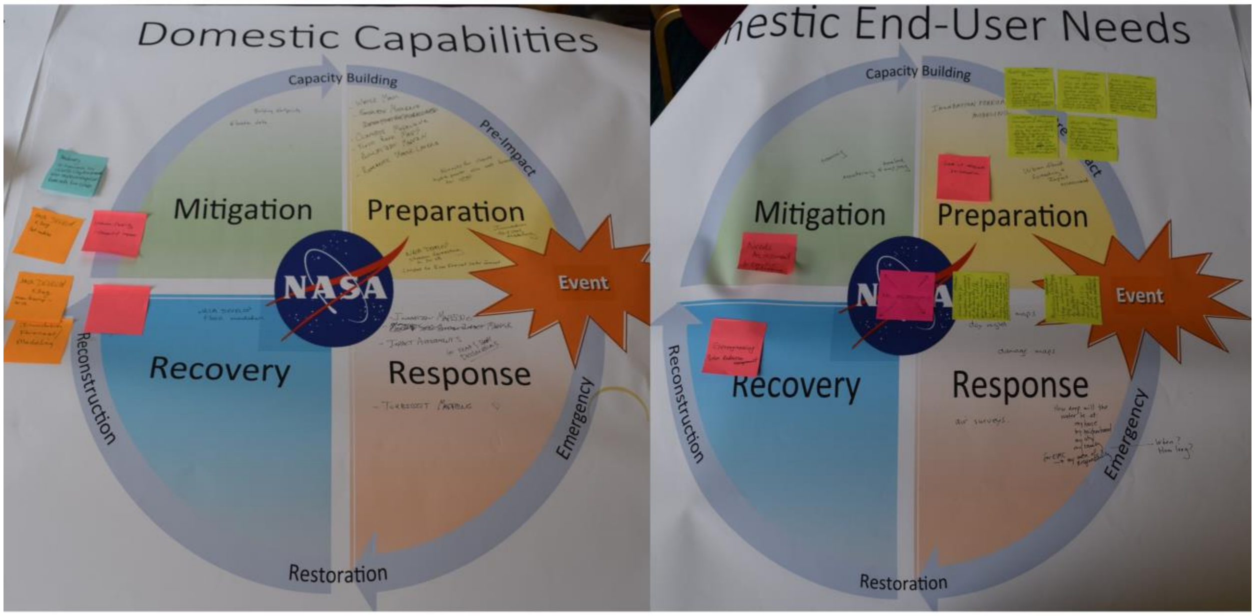

Figure 3.1. NASA ASP posters illustrating the interconnectivity between the different tasks/roles during (flood) disasters.

Table 3.1. presents a concise summary of the results of this exercise.

Table 3.1. Summary of feedback from the poster exercise. C and N in bold denote "Capability" and "Need", respectively.

Mitigation	Preparation	Response	Recovery
C/N: Needs Assessment	**C/N:** NCCHE-Univ. MS-To provide automated Dam-Break Flood model/map & consequence analysis sys. In collaboration w/FEMA. Looking to add additional capabilities in collaboration w/partners.	**N:** Day/Night Maps	**C/N:** Geoengineering
C/N: Service Planning	**C/N:** Modelling challenge - Numerical Model over large domain & long term but able to capture finer features -Runs fast, it is reliable & can work w/different levels of data availability	**C/N:** Crisis Maps	**C/N:** Solar Radiation Management
C/N: Monitoring & Baseline Mapping	**N:** Urban Flood forecasting & input assessment	**C/N:** Damage Maps	**C/N:**
C/N: Training	**C/N:** Modeling Challenges DATA- Stream cross-section data not avail. DEMs have many errors Levee info only avail for National Levee Database. What about remaining 100,000 miles of levees?	**C:** Air surveys	**C/N:**
N: Building Footprints	**N:** Challenges of Consequence Analysis. Asset info available only by census block, not by coordinates leading to probs. How to interface flood depth map w/bldg or critical infrastructure of lifelines data.	**N:** How deep will the water be at my: house, neighborhood, city, community?	**C/N:**
C/N: Elevation data	**C/N:** Modeling question- Are we effectively using the new data sources available for hydrologic & hydraulic modeling? Should we rethink some of the things we are doing?	**C/N:** For EMC- My area of responsibility- When and How long?	**C/N:**
N: Urban Flooding Forecast of Impacts	**N:** Modeling challenge- Providing highly automated systems (web-based) for flood modeling & consequence analysis in faster than real time on the fly, quick & dirty but best as possible.	**C/N:** Inundation Mapping	**C/N:**
C/N: NASA DEVELOP- Flood Inundation	**C:** AIMS Web Service-(Agricultural Integrated Mgmt Sys) is being developed by NCCHE in collaboration w/USDA-ARS. It provides automated watershed analysis. **N:** We are interested in fusing various geospatial data feeds, hydrology layers, etc.	**C/N:** Impact Assessments for FEMA State Declarations	**C/N:**
C/N:	**C:** Dewberry-Do forecasts for clients (hydropower) also meteorological forecasts for cities	**N:** Turbidity Mapping	**C/N:**
C/N:	**C/N:** NASA DEVELOP-Stream forecasting in SW VA Compare to River Forecast Center Forecast	**C/N:**	**C/N:**
C/N:	**C/N:** Water Mask, Floodplain Model, Climate Modeling, Flood Risk Maps, Population Mapping, Reference Water Layers	**C/N:**	**C/N:**
C/N:	**N:** Lack of adequate information	**C/N:**	**C/N:**
C/N:	**N:** Inundation Forecast Modeling	**C/N:**	**C/N:**

4 Breakout Session 1: Existing Response Systems

Four parallel sessions were run on day 1 where each group discussed the capabilities and limitations of current response systems. Sessions were organized by subject matter and included “optical imagery”, “radar/microwave”, “models and mapping”, and “product dissemination and delivery”. Each group discussion was chaired by one or two experts in the subject matter and each session group was given the three tasks below to work on:

- What are the current NASA capabilities with respect each session topic?
- What are the past, current and expected challenges/gaps to be worked out in the next 1-3 years so that assistance offered by NASA to support decision-making and flood response operations can be improved?
- Identify top three immediate/near-term “action items” that need to happen to address identified challenges.

The following subsections summarize the main outcomes of these group sessions.

4.1 Optical Imagery

4.1.1 *What are the current NASA capabilities?*

MODIS (250m – 1km),

LANDSAT (30m),

VIIRS (375m).

Future: Incorporate/make use of: EU satellites that will have VIIRS capabilities (morning); Russian and Korean in early morning orbit (it would be helpful to know what is coming; will it be freely available and can it be accessed easily?

Generally, the challenge is to integrate data/routines from different sensors.

4.1.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Cloud cover (which obstructs direct view of the flood in the case of optical sensors);
- Difficult to ground-truth satellite flood maps;
- Flooding below tree and other vegetation canopy;
- What is missing is very detailed and frequent information on flooding at building scale;
- Inundation mapping seems to be working but how does one assess impact to infrastructure which depends on much more, such as soil moisture, baseflow in rivers, type of soil, type of tide, etc.;
- What is “normal water”, especially a challenge with very high resolution imagery for which a base layer that allows identification of floods becomes a challenge;
- How can one differentiate between man-made and natural water surfaces? Incorporation of global land cover (ex. MODIS 250 m, static) is needed;
- Different users have different expectations. How to meet different expectations or data/information requests;
- Format issues/wishes: data is coming in a particular format and getting data and reformatting is challenging and often no resources. Huge amounts of data;

- Need to standardize data (NetCDF, HDF5) but users often want it different.

4.1.3 *Top priority "action items"*

- What does the world look like under "normal" water conditions? Building a global ephemeral water mask (MODIS: Dan Slayback);
- Derive better cloud masking;
- Urban flood maps are needed: 250 m is coarse; is LIDAR a solution? MODIS image interpreted using LiDAR data has a lot of potential but is very location specific. Getting higher resolution optical imagery;
- Developing blended products (VIIRS/LANDSAT/MODIS, etc.).

4.2 Radar/Microwave

4.2.1 *What are the current NASA capabilities?*

- Current platforms: SMAP radiometry, AMSRE, AIRMOS, GLISTIN-A, AIRSWOT, UAVSAR;
- Alaska Satellite Facility: SAR data (from other agencies international and domestic);
- Agreements with CSA, JAXA, CSK (JPL/ASI), Sentinel 1A+B;
- Processing system: ARIA.

4.2.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Mostly experimental mapping/platforms, only some continuous platforms: is capability operational;
- ARIA -> flooding, extent experimental (shapefile);
- Networking/coordination of efforts (identify flood region of interest to work on). Collaborate with FEMA (C. Vaughan) for "events" testing;
- No NASA L-band in space for flooding beneath canopy;

4.2.3 *Top priority "action items"*

- Need: high res (<20 m) acquisition and rapid mapping of flood extent (one-hour latency). Need commercial/public partnership;
- L-band SAR -> Agreement with Argentina SAOCOM (CONAE) -> one of two satellites launched next year (helps also NISAR);
- Incorporate other NASA centers' SAR mapping capability (in addition to ARIA);
- Combining optical/SAR imagery;
- Relate timing of flood wave and conditions to flood map on image.

4.3 Models & Mapping

4.3.1 *What are the current NASA capabilities?*

- SSBN Ltd/U. of Bristol global hydraulic model at 90 m resolution: provide free hazard layers of flood flow return periods, not run in real-time;
- NOAA National Water Model (NWM): no inundation mapping at present;

- Crest model: no good inundation capability;
- Limited-region NASA modeling;
- Land Information System (LIS): simple routing;
- Global Flood Monitoring system (GFMS):
    - Operational, products every 3 hours, calculations up to near real-time, use global NWP forecast model to extend out to 5 days.
    - 1/8-degree resolution, 1 km routing calculation, inundation estimate.
    - Validated, papers published; comparisons to MODIS inundation, SAR, streamflow, Dartmouth Flood Observatory database.
    - Uses VIC model: land surface model.
    - Part of NASA training for remote sensing (ARSET);

4.3.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Need incorporation of dam, levees, and bridge modules in models, better contact with dam owners, elevation of dam crest/bottom topography information in National Inventory of Dams (NID);
- Improved mesoscale atmospheric forecasting/flash flooding/urban flooding;
- Need for fast turnaround for flood model outputs, limited by satellite precipitation observations (currently 3 hours, Global Precipitation Measurement Mission GPM is reducing latency, increasing temporal resolution to 30 mins);
- Need multiscale modeling, higher spatial resolution of models, higher resolution routing (under 1 kilometer), translates to higher resolution mapping and geospatial information for decision-makers;
- Need for more routine validation;
- Need for better free global DEM (especially for hydraulic modeling);
- Improved remote sensing-derived channel location dataset (Landsat is being used to do this now as part of the SWOT mission);
- High resolution models require accurate precipitation forcing (where and when, precipitation rate).

4.3.3 *Top priority "action items"*

- Make high-resolution model output and other data easily available, for free;
- Closer integration of models and observations, including for use in validation and assimilation;
- Start making data more intuitive to end users, put it into basic terms.

4.4 Product Dissemination & Delivery

4.4.1 *What are the current NASA capabilities?*

- Each agency should make a list of the tools and products they have: keep an updated list;

- NASA Disaster Program: Inventory of all relevant data products will be available on website;
- Split into Data & Products;
- Issues with Data:
    - Accessibility
    - Restrictive license
- Products are free and open: geo-located and transported into layers;
- Difference between data and products can be vast;

4.4.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Data interoperability;
- Getting satellite data in a timely fashion;
- Make sure all stakeholders have access to data;
- Sensitivity about format of services; keep in mind different types of services;
- Instability of Internet connections in the international arena (bandwidth issues);
- What are the needs of the communities, engagement with the community is lacking;
- Format needs: JPEG is low resolution;
- International Charter: How do we find who the user community is? They change all the time. How can we track them?
- Coordinate with USGS and USACE what happens with areas in-between the river gauges, and in ungauged areas;
- Outside the U.S. and Europe there is no structure; there is a lack of capacity;
- Simplicity and timeliness are very important;
- There is a lack of skill on predicting impacts ahead of time;
- Accuracy of data lacking and lack of knowledge about the impact of the extent of the flood.

4.4.3 *Top priority "action items"*

- Improving response methods to deal with issues (e.g. summarization, bandwidth sensitiveness);
- Study and understand vulnerability; tapping more in social sciences; researching risk perception;
- Link up the scientists with the user community;
- Create a Flood Advisory Group, complemented with services available to the end-users;
- More need for translators and "mediators" of science and forecast;
- Create outreach program that covers a wide area of actions and activities (where students can get involve and recommend action items for local communities).

5 Breakout Session 2: Improving Flood Response Coordination

In the morning of day 2, again four sessions were run in parallel where this time each group discussed how to improve flood response coordination. Sessions included "integration of flood data from different sources", "improving flood products through interagency collaboration", "role of international organizations", and "building public-private partnerships". Again, as with breakout session 1, each group discussion was chaired by one or two experts in the subject matter and each of the breakout groups were given a main task below to work on:

- Integration of flood data from different sources
- How do we best inform each other about capabilities/products?
- How can international organizations support and better collaborate to improve flood response at a global level?
- How (in what form) can the private sector assist in improving the use of EO data in flood response?

Again, each session group also needed to identify challenges that need to be addressed in the short-term and identify action items to address those. The following subsections summarize the main outcomes of these group sessions.

5.1 Integration of Flood Data from Different Sources

5.1.1 *How can we best integrate different flood data/products to maximize capability/information?*

- Down-sample to a common pixel size for each product;
- Make each a separate layer so they can be clicked on and off on a map;
- Make the tools distributable and accessible/discoverable;
- Using a common projection, same pixel sizes, make them all geo-located, open formats;
- Note on the map the exceptions (mountain shadows, cloud shadows, clouds) and differences between various model outputs and maps from imagery (showing where the differences occur). so the mappers and modelers could obtain quantitative feedback;
- Come up with fusion techniques through agreements on how to present past, current, and future acquisitions;
- Use open-access cloud platforms to store and manipulate flood products;
- Have agencies, which sign licenses, implement an automated signature layer or allow common creative license that allow humanitarian and research use of restricted license data to certain requesting organizations.

5.1.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Determine what the users/requestors want to use the product for first in order to figure out what the needs are, what accuracy is acceptable, and how to develop and implement a common approach to data fusion;
- Have all the tools on one platform;
- Very often products are in different projections, different pixel sizes, different geolocation accuracy, different formats;

- How to capture quantitative feedback to improve the product accuracy and usefulness
- How to automate different functions to better deliver and handle the increasing data volumes, in addition to automated visibility into current and upcoming acquisition footprints;
- How to cut-out a subset of the image to just the area of interest before downloading;
- Licensing issues limit access;
- How to show spatially adjacent scenes on the same map and their acquisition sequence.

5.1.3 *Top priority "action items"*

- Leverage social media to poll for products (Doodle), post products (Twitter), share products (Facebook);
- Setup a platform organized by event, but also by location and date for each product.
- Improve the detailing of use cases, defining of user categories, and delineating the flow from raw data to finished product. Include in this how end-users can subscribe to be notified and supplied a link to the product they want for each supplier. Based on common, open, standard practices - starts with requiring a product distribution plan to be included in all new grant proposals and all NASA Center disaster work or at least sign-off on the HQ published dissemination plan/procedure/playbook;
- Pursue agreements with US agencies that purchase license-restricted data to open the user list to include ALL government personnel.

5.2 Improving Flood Products through Interagency Collaboration

5.2.1 *How do we best inform each other about capabilities/products?*

- Need to identify NASA points of contact, either at regional level or by group, incorporated into Playbook;
- Need ability to quickly reach out ahead of events, but also on an ongoing basis for sharing research/products;
- Suggest single NASA HQ contact to direct inquiries, similar to how activation of Charter triggers coordination from other agencies – this now exists at HQ, with coordinators at each of the centers;
- How will NASA handle multiple requests from states, counties, etc.;
- Responsibility for partner agencies to also provide names for points of contact for NASA to be reaching out to;
- FEMA brings additional agency representatives with expertise to EOCs, NASA may want to coordinate with FEMA on this topic;
- Need one-stop-shop for community to learn about new products and how to use them so that end-users can effectively use them – this is application and research focused:
    - NASA SPORT is doing this with NWS;
    - SERVIR is working with end-users and organizations internationally;
    - USGS is user of NASA change detection product, working with surface water team to take "water boundary mark" for pilot project;

  - This coordination will help understand user needs.

5.2.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Playbook needs to be finished and publicized:
  - Other agencies can provide input to refine;
  - Use in exercises.
- Products pushed to HDDS for distribution;
- Appoint NASA point of contact and publicize to partners:
  - Summary list of products shared with FEMA/State Emergency Managers;
  - Go to conferences and forums and present (IAEM yearly meetings, FEMA high-end conference – including training session opportunities).
- Improve latency issues, higher frequency updates;
- Need higher spatial resolution of tools for localized modeling and mapping capabilities:
  - Issue of data size;
  - Overlays needed in Google Earth format, ESRI web services, other public formats.
- NASA needs plan to identify top products through vetting process and plan to transition to operations at other agencies:
  - These may be used for high value decisions, what is the requirement for product reliability/accuracy;
  - Requires feedback from end users.

5.2.3 *Top priority "action items"*

- Participate in FEMA/IAEM conferences (booth, training, presentations, etc.);
- NASA creates curated website for specific events to connect users with relevant data sources and products;
- Ensure communicating this to partners.

5.3 Role of International Organizations

5.3.1 *How can international organizations support and better collaborate to improve flood response at a global level?*

- Start an end-user partner meeting (through the Global Flood Partnership?);
- One-stop-shop that can tell who is doing what in which region would be useful. Have contact points in each organization: ensure sustainability of the community of practice;
- NASA disaster data user group – constant stream of feedback would be useful;
- Feedback during emergency is challenging but needed – narrow window when handing over data to end-user.

5.3.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- Better access to data is the primary challenge;
- Difficult for the lay person to identify the optimal data to use;

- Need to make data interfaces attractive and intuitive: ongoing NASA projects are addressing some of these issues;
- Need to define who is the end-user of the data;
- Not just flood info, others such as asset population, and other multi-hazard approach needed;
- Funding shortfall.

5.3.3 *Top priority "action items"*

- Evaluation of the data/products/capability available;
- Stock taking of the current user capacity for emergency response (e.g. Philippines has state-of-the-art, in this case we defer to the country capacity);
- Lots of conversations on collaboration in the past – need sustained effort to establish the Community of Practice.

5.4 Building Public-Private Partnerships

5.4.1 *How can the private sector assist in improving the use of EO data in flood response?*

- NASA ESTO-AIST (Michael Little) may be a good basis to form these partnerships;
- NASA could leverage on existing private sector government contract capabilities;
- Private sector could provide assistance in making sense of the science & models to the Emergency Manager needs;
- Private sector could provide expert and "extra" assistance in image acquisition, processing and modeling (crowd sourcing, Google Crisis, Cloud Compute, Geospatial standardization, GEE, etc.);

5.4.2 *What are the challenges to be worked on in the next 1 to 3 years?*

- User feedback enabling tools (FCC, Broadcasting);
- Training aspect involvement (ARSET & private sector): private sector receives a lot of feedback from clients, a lot of expertise how to approach users to explain value of products;
- Disconnects between private and public activities: solving the same problem, so should connect.

5.4.3 *Top priority "action items"*

- NASA-owned standardization widget for mission & research data;
- Communication: turn science into meaningful valuable text;
- Private (user) conferences attendance (PI attendance) to talk about NASA product value. NASA Enterprise License Management Team.

6 Summary Diagram of "Challenges & Action Items"

The diagram below summarizes common threads from the breakout sessions to lay out recommendations and a possible 1- to 3-year action plan.

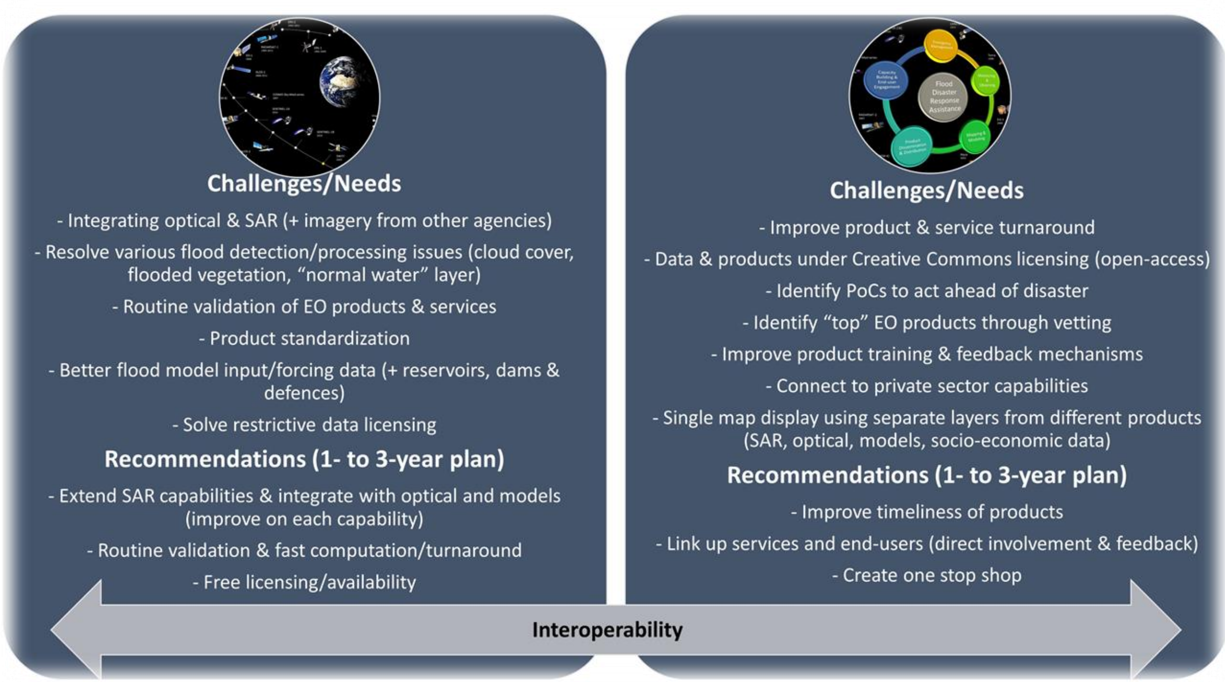

Figure 6.1. Summary diagram of common threads in system capabilities and the flood response communities (synthesis of sections 4 and 5).

7 Technology/Capability/Expectation Matrix

Table 7.1. List of available EO products and services with potential for flood response assistance, including capabilities and expectations.

System	Organization*	Operational	Data/Service Type	Caveat/Need	Level of Expectation**
MODIS NRT flood maps	NASA/GSFC	Yes	MODIS mapping	Cloud masking; Integration of SAR & uncertainty	High
Dartmouth Flood Observatory (DFO)	NASA/University Colorado, Boulder	Yes	MODIS-based mapping. Also, includes mapping from other EO imagery during selected events		High
River Watch (DFO)	NASA/University Colorado, Boulder	Yes	Radiometry-based discharge	More sites needed; linking with flood model	High
VIIRS/NPP	GMU/NOAA	No	Flood mapping	How to integrate with GSFC/DFO efforts	Moderate
International Disaster Charter	Multiple agencies	Yes (triggered)	Satellite imagery	----	High
GFMS	NASA/UMD	Yes	Computer model & GPM data	Resolution; validation	High
GFDS	GDACS/JRC	Yes	Flood detection system (mainly based on radiometry Q)	How can this be integrated with NASA efforts	Moderate
ARIA	NASA/JPL	Ad hoc w/external data coordination	Multi-hazard mapping platform from various satellite data	Non-operational; more resources/funding required?	Low
G-POD Sarotec	ESA/LIST	Yes but in pre-operational status	On demand flood mapping from SAR	Still in “beta” testing mode; need to move this out of testing phase & complement with NASA efforts	Low
GFP/GFWG	Global Flood Partnership	NA	Working group	May be ideal to gather feedback; link products closer to user and organize training sessions?	Moderate
CEOS Flood Pilot	CEOS	No	Flood pilot (R&D)	Need to ensure continuity of this pilot and related efforts (e.g. image licensing)	Moderate

*Note that most systems listed require ongoing funding support

**The level of system/product performance and operationality that the end-user or decision-maker can expect

8 Action Plan for Coordinating Flood Response

The morning of day 3 was essentially the workshop wrap-up session and the summary of the workshop is provided in Section 1.2. During the workshop wrap-up session, participants were asked to team up according to their discipline (the teams formed are shown as column headings in Table 8.1) in order to discuss an action plan for better coordinating flood response. This action plan is made up of the top priorities this “Flood Response Community” defined (Table 8.1). The following sections list these priorities in detail.

Table 8.1. Top priorities for the Flood Response Community

Emergency Management	Monitoring and Observing	Mapping and Modeling	Product Dissemination and Distribution	Capacity Building and End-User Engagement
Push data and products out in 12- to 24-hour intervals, within capabilities (ask for assistance with resources as needed and manage expectations)	One-stop-shop (should also include future acquisitions), where communities can pull rather than push data and products	Automated polygon generation of flood disaster location to target Earth observation data acquisition and products, especially at the international level	Single access point (one-stop-shop) that allows automated product delivery system	Build trust in the products and report value to community: One-stop-shop needs to have products that are tailored to user needs and allow for feedback

8.1 Emergency Management

- Push data and products out in 12-24 hour intervals, within capabilities (ask for resources help as a community) → manage expectations

8.2 Monitoring and Observing

- One Stop Shop (Central Clearinghouse) → Collection Management Tool (USGS example) → Data Producers need to receive requests for data → improve spatial databases and also include future acquisition;
- The Texas May/June 2015 flood disaster could be used as a “replay” to test out such an “improved response coordination”: Gordon Wells could assist with this Texas replay.

8.3 Mapping and Modeling

- Automated polygon generation of flood disaster event location (esp. internationally): look at PDC – Disaster Alert App, Flood List, GDACS, etc.;
- Need for a high-accuracy global DEM, also high-resolution map of true channel network (cf. SWOT mission effort with Landsat series), levees, etc. (medium term);
- Coordinate feed for real time events (shapefile, coordinates);
- One-stop-shop: access to different sources of imagery with low latency; aggregate flood maps from different sources but keep separate layers.

8.4 Product Dissemination and Distribution

- Single access point (one-stop-shop): include ranking of relevance of products and link to other clearinghouses, e.g. USGS HDDS and other agencies;
- Need automated product delivery system;
- Indication of how much effort NASA puts in an event response: this links to importance of feedback.

8.5 Capacity Building & End User Engagements

- Build trust in the product and report value to the community;
- Tailored clearinghouse tool to pull data/products that people need; keep record and update who the users are and who has and can have access: "marry up knowledge and people";
- Be cautious about "intruding" the private sector product generation.

9 Appendices

9.1 Appendix A. Summaries of NASA-funded flood-related projects

Damage Assessment Map from Interferometric Coherence

Principal Investigator: Sang-Ho Yun.

This project develops algorithms to produce reliable damage detection maps of natural disasters using Interferometric Synthetic Aperture Radar (InSAR) coherence, which will guide decision making, disaster assessment, response and recovery activities of international, federal, state and local agencies, including the World Bank and USGS. Our algorithm provides a day-and-night and all-weather synoptic view of damage detection map covering a few thousand square kilometers from imaging radar mounted on a spacecraft/aircraft, enables rapid response, providing decision support information to key partners and stakeholders for timely situational awareness.

Enhancing Floodplain Management in the Lower Mekong River Basin Using NASA Vegetation and Water Cycle Satellite Observations

Principal Investigator: John Bolten.

The existing Soil and Water Assessment Tool (SWAT) used for flood forecasting and floodplain management of the Lower Mekong River Basin is prone to errors due in part to outdated Land Use/ Land Cover (LULC) mapping (i.e., the current map was derived from 1997 data), unrealistic characterization (and lack of in-situ observations) of Available Water Capacity (AWC), flooding extent, and inability to quantify the effects of changes in basin dynamics. This project seeks to enhance regional planning and cooperation for water resources in the Lower Mekong Basin by delivering enhanced and updated products in Soil Moisture, Evapotranspiration (ET), Land Use / Land Cover (LULC), Soil Hydrologic Parameters (SHP), Flooding, and Suspended Sediment to the Mekong River Commission (MRC). The project is also building a customized Graphic Visualization Tool (GVT) to work in concert with the output of the SWAT model parameterized for the Mekong Basin as an adjunct tool of the Mekong River Commission (MRC) Decision Support Framework. Project Mekong is establishing a long-term collaboration between NASA, USGS, educational institutions (Texas A&M, University of South Carolina) and several stakeholders in the Lower Mekong River Basin (LMRB), including the MRC. The project is envisaged to provide improved floodplain modeling, management, and flood mitigation and decision making for the entire LMRB, which could positively impact millions of people who live in the region.

Near Real Time Flood Inundation Prediction and Mapping for the World Food Program, GeoSUR, and USAID/OFDA

Principal Investigator: G. Robert Brackenridge.

The goal of this project is to produce specialized products, based on processing NASA orbital sensor data to map floods in near real time, and transfer these products to operations as high-end decision support assets for partners and end users. The planned operational data products include near-real time optical flood mapping, microwave-based river discharge measurements, flood risk maps, and flood extent (inundation) prediction. This fundamental flood mapping product is used extensively by Flood support research and response communities including 3 of our currently active projects.

Real-time Global Flood Analyses and Forecasts Using Satellite Rainfall and Hydrological Models

Principal Investigator: Robert Adler.

The Global Flood Monitoring System (GFMS) was developed under NASA ROSES DISASTERS 20008 using TRMM/TMPA precipitation and land Surface and routing models to support Disaster Response Plan. It is a core ASP Disasters capability for flood events. Real-time results at flood.umd.edu. The Global Flood Monitoring System (GFMS) is currently using NASA multi-satellite precipitation data and the Dominant River routing Integrated with VIC Environment (DRIVE) hydrological model system. The next phase of the implemented system will utilize Global Precipitation Measurement (GPM) multi-satellite data, involve Numerical Weather Prediction (NWP) forecast precipitation information to extend the calculations a few days into the future, and involve improved model elements (e.g., high resolution inundation maps, a dam/reservoir module) and improved data displays and access capabilities. NASA-based data sets of precipitation (TRMM and GPM), land surface characteristics (e.g., soil moisture, elevation, land cover), and hydrological and meteorological models will all be used to improve global and regional flood detection/monitoring/forecasting information used as input to decision making processes for use in disaster management, response, preparedness and mitigation activities.

Global Flood and Landslide Monitoring and Forecasting

Principal Investigator: Frederick Policelli.

This project is designed to improve reliability of MODIS Flood Map products by addressing intrinsically difficult data challenges presented by false positive elements in the data due to terrain, cloud and other effects. This Project spun-off from earlier work supporting the Adler and Breckinridge Flood projects. The experimental system is running at http://oas.gsfc.nasa.gov/floodmap/ . It is also used substantially as a first-guess field for rapid response to flood by our Near Real Time Flood Inundation Prediction and Mapping project.

A Remote-sensing-based Flood Crop Loss Assessment Service System (RF-CLASS) for Supporting USDA Crop Statistics and Insurance Decision Making

Principal Investigator: Liping Di.

The goal of this project is to fully develop, evaluate, and operate a remote-sensing-based flood crop loss assessment service system, the RF-CLASS, for supporting crop statistics and insurance decision-making in two USDA agencies, the National Agricultural Statistics Service (NASS) and Risk Management Agency (RMA). This project will greatly improve the efficiency and effectiveness of flood-related crop decision-making at USDA, shortening by a factor of at least 10 the time needed for the decision makers to obtain decision-support information, and significantly improve the objectiveness and reduce cost for decision-making.

Development of and Integration of a High Resolution 2-D flood Model with Satellite Flood Data

Principal Investigator: Guy Schumann.

Focusing on the cities of Houston and Dallas, and the town of Cuero, the major thrust of this project is to build a high-resolution two-dimensional hydrodynamic model that will simulate the "best" inundation re-analysis of the flood events in locations (including urban settings) where LiDAR floodplain data and gauged rainfall and river flow data are available; and to integrate the model event re-analysis and the satellite flood data to demonstrate the uniqueness of these available multi-temporal and multi-resolution imagery in combination with the model.